Carrageenan Industry Market Overview

13

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Abstract

Carrageenan is the leading seaweed-derived food hydrocolloid and is used widely for its textural functionality. Carrageenan has a specific set of rheological properties that differentiates it from other hydrocolloids and renders it useful in certain processed foods in addition to a small number of other niche markets. Growing demand for processed foods is a global trend that is being driven in general by an increase in population but also by opposing changes in the world's economies. On one side, recession is forcing consumers to seek value for money, on the other, improved living standards in formerly disadvantaged economies are enabling consumers to look for more diverse and luxurious product offerings. From either perspective, carrageenan is a winner and the global market is expected to grow albeit, there are some indications that growth in certain regions and sectors has slowed.

This chapter provides a general overview of the global carrageenan industry with a particular focus on the market dynamics for *Kappaphycus* and *Eucheuma.* Below we present information on: production of *Kappaphycus* and *Eucheuma* seaweeds as raw materials; carrageenan production and use in end-markets. We also present data on pricing, key players and capacities and round off with a general discussion of the current and potential trends that are influencing the industry. In all of this, we take an industry-based approach.

13.1 Introduction

The carrageenan market is the largest of the seaweed-derived, food hydrocolloid markets and currently holds the fourth largest share (in $ value) of the wider global hydrocolloids market, behind gelatin, starch and pectin (Seisun 2016). In 2014, the global hydrocolloids market was valued at US$ 5.4 Billion but projected to reach US$ 7.6 Billion by 2020 (Markets and Markets 2016). Industry estimates for 2015/2016 put a value of US$ 600–700 Million on the global carrageenan market (Hotchkiss et al. 2016b; Seisun 2016) with a projected average growth of ≈ 3% per year (CAGR). Most recent market research predicted that the global market for carrageenan would approach US$ 1 Billion by 2024 (FMI 2017).

Current industry estimates for the global production capacity of carrageenan range from about 70,000–80,000 MT dwt year^{-1} (Porse and Ladenburg 2015; CyberColloids own data) to over 110,000 MT year^{-1} (Neish 2015). CyberColloids' estimate for current global usage, as based on end-sales data, is for 68,000 MT dwt or approximately 80% of the estimated production capacity (CyberColloids own data). Most of this carrageenan (≈90%) comes from species and strains of *Kappaphycus* and *Eucheuma* or "cottonii" and "spinosum" respectively as they were referred to historically and still are by the industry. In 2016, CyberColloids estimated the global production of *Kappaphycus* for the carrageenan industry to be in the region of 1.5 Million MT wwt or 200,000 MT dwt (Hotchkiss et al. 2016b) with most cultivation occurring in Indonesia and the Philippines. *Eucheuma* is not cultivated on such a large-scale

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as *Kappaphycus*, current estimates put production for the carrageenan industry in the range of 0.3 Million MT wwt or 40,000 MT dwt (Hotchkiss et al. 2016b). It must be noted that a substantial market for sea vegetables also exists which is not included in these estimates. The remainder of the carrageenan produced comes from cold-water species that are harvested mostly in South America, approximately 15,000 MT dwt and from the dwindling remnants of a small, traditional N. Atlantic industry which produces only a few hundred dry MT annually from *Chondrus crispus* (CyberColloids own data).

A note on information sources: much of the information and data presented here is CyberColloids' own data that have been obtained by permission and interview with carrageenan industry contacts including processors, end users and other hydrocolloid experts. Where relevant, we have included our interpretation of "industry gossip" and review of activity as reported in the industry media. All other data sources are appropriately accredited.

Building an accurate picture for the dynamics of any global market such as carrageenan is a difficult task and one that is reliant on obtaining realistic and representative data across a world-wide, value-chain. Consequently, very few industry based reports for carrageenan are available. The approach we use here draws heavily on the combined expertise of CyberColloids and our network of industry contacts. The sales and production data we present are based on farm-gate statistics and industry intelligence and most importantly, bottom-up estimates of seaweed production are corroborated by top-down estimates of carrageenan production and end-use markets.

Where possible, we have put our data into context with that of other industry experts. It must be noted that direct comparisons are difficult given that industry market intelligence varies significantly and is often regionally biased (i.e. both over- and under-emphasis on certain markets and sectors). Extrapolation of data sets is inevitable and all players utilise different conversion rates/yield ratios based on their own particular experiences. However, in accepting all of the above it appears that most recent analyses are acceptably close.

13.2 Global Production of *Kappaphycus* and *Eucheuma* Seaweeds

Most of the world's carrageenan (≈90%) comes from *Kappaphycus* and *Eucheuma* seaweeds that are cultivated mainly in Indonesia and the Philippines. Significant production for export markets has also been achieved in Malaysia, Zanzibar in the United Republic of Tanzania and Madagascar (Fig. 13.1). Commercial production is growing in other parts of south-east Asia such as Vietnam, Cambodia, Myanmar, East Timor and southern China; in some Pacific Islands including Hawaii, Fiji, Kiribati and Solomon Islands; in mainland East Africa, Mozambique and Kenya and in the South and Central Americas including Argentina, Colombia, Brazil, Ecuador, Venezuela, Mexico, Peru and Panama.

Recent industry estimates put the global production of *Kappaphycus* in the region of 170,000–200,000 MT dwt and *Eucheuma* in the region of 40,000–45,000 MT dwt (CyberColloids own data; Neish 2015; Porse and Ladenburg 2015). Since the late 2000s Indonesia has been the world's largest producer of *Kappaphycus,* surpassing the Philippines, which had been the major producer since the 1970s, when large-scale cultivation of these seaweeds began (Hurtado et al. 2015). Today, Indonesia produces an estimated 110,000 MT dwt of *Kappaphycus* (Fig. 13.2) of which, about 70% was exported (Porse and Ladenburg 2015). The Philippines produced an estimated 60,000 dry MT (Fig. 13.2). Neish

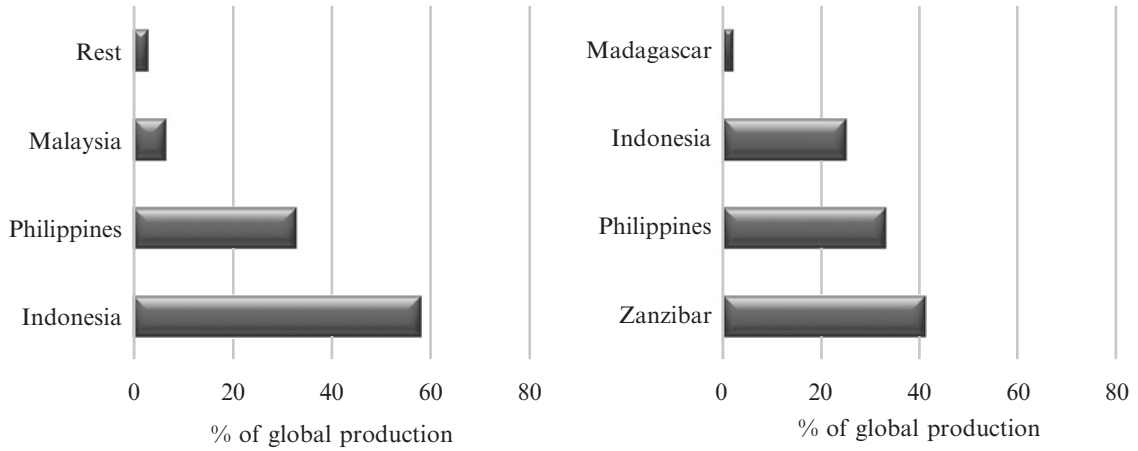


Fig. 13.1 Global production of *Kappaphycus* (*left*) and *Eucheuma* (*right*) in 2012 showing the relative split between major producers. NB: For *Kappaphycus* "Rest" includes Vietnam, Madagascar, India, Rep. of Tanzania, Central/South Pacific Islands and East Timor (CyberColloids 2012)

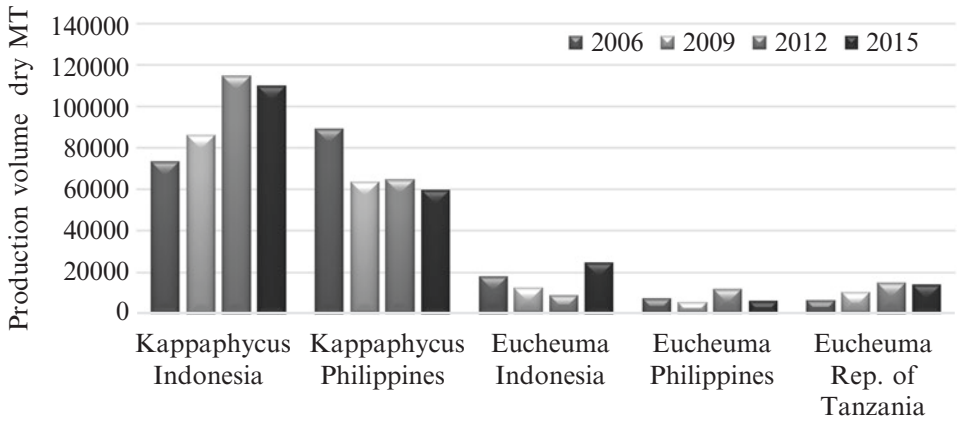


Fig. 13.2 Average annual production of *Kappaphycus* and *Eucheuma* (in dry MT) in the major producing regions from 2006–2015 (Based on the following sources: CyberColloids own data; Dakay 2010; Bixler and Porse 2011; CyberColloids 2012; Porse and Ladenburg 2015)

(2015) reported that the Philippines also imported around 50,000 MT dwt of seaweed from Indonesia for processing.

Kappaphycus has been the primary carrageenophyte seaweed used to establish commercial farming enterprises outside of Indonesia and the Philippines. These industries are relatively small on a global level. Production in Vietnam, Madagascar and India was typically in the range of 1000–2000 MT dwt year^{-1}, whereas in the Republic of Tanzania, Central/South Pacific Islands and East Timor volumes of 100–500 dry MT were reported (CyberColloids 2012).

In the last 10 years (i.e. 2010–2017), growth in production of *Kappaphycus* in Indonesia has been considerable, with a 50% increase in production during this period (Fig. 13.2). Since 2009, production of *Kappaphycus* in the Philippines appeared to have remained fairly stable (Fig. 13.2) but this trend followed a significant decline in production (in the region of 25%) after the 2008 industry "crisis", which initiated a re-balancing of global supply and demand for carrageenan (CyberColloids 2012). The combined outcome was that, as of 2017, Indonesia produced around 58% of the global *Kappaphycus* crop (CyberColloids own data, Porse and Ladenburg 2015).

Eucheuma is not cultivated on such a large scale as *Kappaphycus* and in addition to Indonesia and the Philippines, much of the world's *Eucheuma* is cultivated in Zanzibar, in the Republic of Tanzania (Figs. 13.1 and 13.2). Production in Zanzibar had been steadily increasing since the 1990s and in 2012, over 15,000 dry MT of *Eucheuma* were exported from there. This represented over one third of the global harvest (CyberColloids 2012; Neish and Msuya 2013). There is no processing of seaweed for carrageenan in Zanzibar and virtually all *Eucheuma* is exported for the production of **a**lcohol **p**recipitation (AP)iota carrageenan for use in toothpaste and food (CyberColloids own data, Neish and Msuya 2013). Although *Kappaphycus* is also grown in the Zanzibar region, crops have generally not flourished and have been subject to repeated failures, unlike *Eucheuma.* In 2012, Zanzibar produced less than 100 dry MT of *Kappaphycus* (Neish and Msuya 2013).

Markets for *Eucheuma* seaweed have been reported as showing "sluggish growth" in recent years. Consequently, there was an over-supply of seaweed and high competition between Indonesia, the Philippines and Zanzibar (Neish and Msuya 2013). In 2012, CyberColloids reported a declining trend for *Eucheuma* production in Indonesia with annual production being approximately half of that in 2006 (CyberColloids 2012). More recent estimates for *Eucheuma* production (Porse and Ladenburg (2015) showed production in Indonesia to have risen to about 25,000 MT dwt in 2015 whilst production in the Philippines appeared to have dropped. Zanzibar however, seems to have remained stable during that period.

13.3 Pricing Dynamics for *Kappaphycus* and *Eucheuma* Seaweeds

With Indonesia dominating the supply of *Kappaphycus,* as of 2017, global pricing strategies typically track the situation in Indonesia. Figure 13.3 shows the average price of *Kappaphycus* (exports in US$ MT^{-1} dwt) from Indonesia over the period 2007–2016. For simplicity, only the changes in pricing have been plotted to show the extremes in price and a trend-line added which indicates a general fall in price, post the price spike in 2008. Prior to 2008, the price of raw material was low, generally due to an over-capacity which kept prices down. This situation was not sustainable and consequentially resulted in the industry re-balancing itself. However, this new balance, between supply and demand and capacity, was too tight, hence the price spike in 2008. Since 2008, global capacity has risen, as has demand (detailed below) and industry prices have not returned to unsustainable levels.

In recent years, the average price for *Kappaphycus* has been dropping gradually, as of March 2017, it was around US$ 900 MT^{-1} dwt (CyberColloids own data). This is partially as a reflection of exchange rates, in particular a strong US$, but also due to a surplus in the supply chain. In 2016,

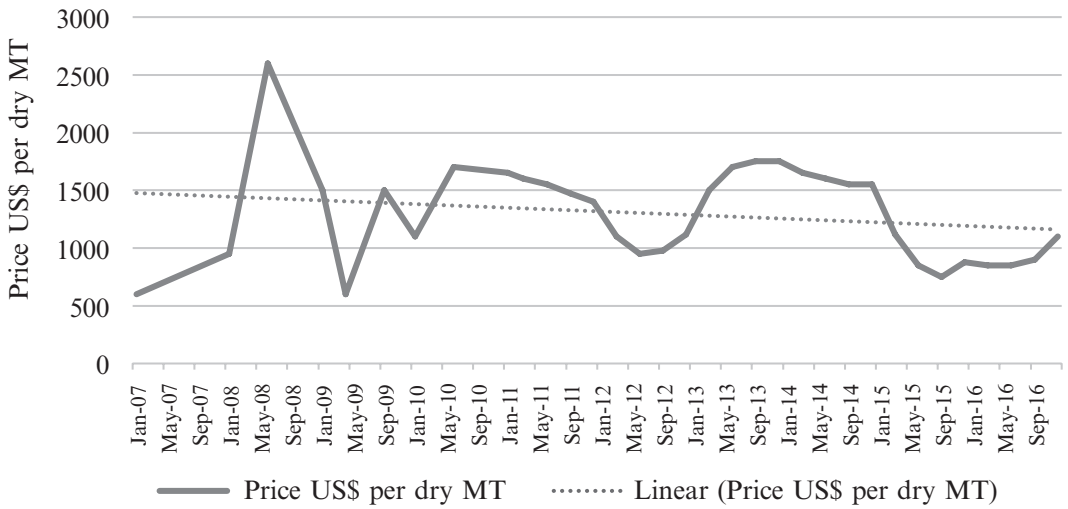


Fig. 13.3 Average price (US$ MT^{-1} dwt) for *Kappaphycus* seaweed from Indonesia from 2007–2016 based on export prices. This graph shows the price spike in 2008, followed by a gradual decline in price. NB: only significant changes in pricing were plotted (CyberColloids own data)

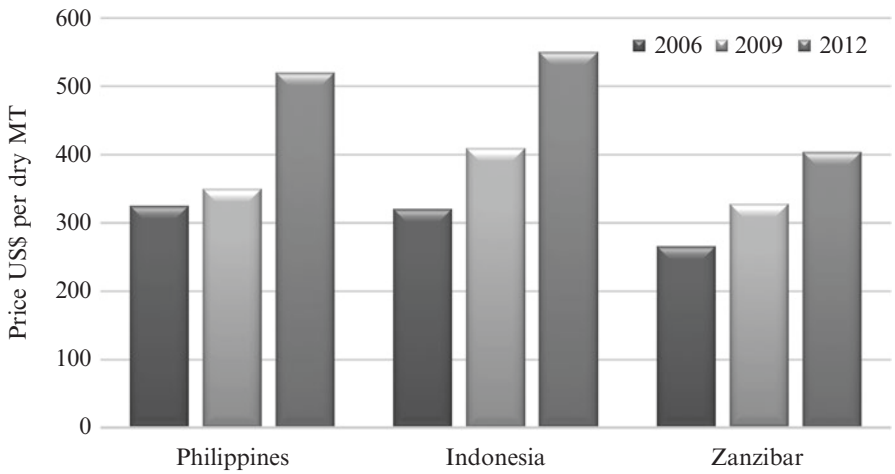


Fig. 13.4 Average price (US$ MT^{-1} dwt) for Eucheumatoid seaweed from the major growing regions from 2006–2012 based on export prices (CyberColloids own data)

there were exceptionally good harvests in south-east Asia, Indonesia in particular, which caused the price of the cultivated seaweed to drop. South-east Asia is currently (April 2017) coming out of a very bad wet season which may further drive prices up, but this remains to be seen.

Currently, most of Indonesia's exported seaweed goes to China (Porse and Ladenburg 2015). The industry is waiting to see whether the Indonesian government will restrict exports in order to create a local 'added value' industry (as currently being discussed within Indonesia) and if so, what this will mean for the future of the carrageenan industry, in China in particular. How the Indonesian situation plays out will undoubtedly have a significant impact and most likely create pricing turmoil if current exports of their seaweeds diminish.

The price for *Eucheuma* seaweeds has historically been much lower than that of *Kappaphycus* (Fig. 13.4). Demand for *Eucheuma* is substantially lower (since there were fewer value applications for iota carrageenan) and there is generally a surplus of raw material supply which maintained the price at low levels. In 2012, farm gate prices for Zanzibar grown *Eucheuma* were in the range US$ 190–250 MT^{-1} dwt. These prices were reported as being lower on average than equivalent prices for Indonesian and Philippines grown *Eucheuma.* However, prices on the open market, at that time, i.e. with freight costs factored in, were more similar due to the higher cost of shipping from Zanzibar (Neish and Msuya 2013). These higher export prices are reflected in Figure 13.4 which shows that the average market price of *Eucheuma* from the major growing regions ranged from US$ 400–550 in 2012. The average market price for *Eucheuma* exported from Indonesia was reported to be about US$ 400 per dry MT in March 2017 (CyberColloids own data).

13.4 Overview of Global Carrageenan Production

Within the food industry, carrageenan is recognised as either "Carrageenan" or "PES – **P**rocessed **E**ucheuma **S**eaweed" however, within the carrageenan industry the terms "refined" and "SRC" (**s**emi-**r**efined **c**arrageenan) are more typically used.

Kappaphycus and *Eucheuma* are used to produce both refined and semi-refined grades of carrageenan. **R**efined **c**arrageenan (RC) is extracted using **a**lcohol **p**recipitation (AP) or **g**el **p**ress (GP) techniques to produce refined carrageenans that have had the cellulosic component (≈15–20% dry weight) filtered out. Alcohol precipitated, refined iota and kappa carrageenan are obtained from *Eucheuma* and *Kappaphycus* spp. respectively. Gel-press, refined carrageenan (kappa) is only extracted from *Kappaphycus* species. SRC is produced using a process that produces a semi-refined grade that still contains the cellulose component of the seaweed tissue. Semi-refined grades of both kappa and iota carrageenan are produced from *Kappaphycus* and *Eucheuma* respectively. For more detail on extraction methods and carrageenan sources see Ortiz-Tena et al. Chap. 12 in this book and Hotchkiss et al. (2016b).

Refined carrageenans are also extracted from various cold-water species of seaweed. AP lambda carrageenan is produced from *Chondrus crispus* (Irish Moss),*Mastocarpus stellatus* (False Irish Moss) and some of the South American seaweeds that contain a relatively high lambda carrageenan content.

An important group of hybrid grades of carrageenan are also extracted from the cold-water species using a range of proprietary processes that are based on alkali extraction, in an alcohol:water slurry and/or selective extraction techniques. These grades, also known as kappa-iota hybrids; kappa-lambda hybrids; "kappa-2-hybrids"; weak-gelling hybrids and heterogenous grades, are a mix of kappa, lambda and iota carrageenan, the exact composition of which depends on the source material and process (see Hotchkiss et al. 2016b for more detail). They are collectively referred to here as: "hybrid grades".

For the purposes of this overview, the following abbreviations will be used to denote the different types of carrageenan: RC = **r**efined **c**arrageenan; SRC = **s**emi-**r**efined carrageenan; AP = **a**lcohol **p**recipitated, GP = **g**el **p**ress. The initial steps in a SRC process produce alkali-treated chips, either ATC (**a**lkali-**t**reated **c**ottonii) or ATS (**a**lkali-**t**reated **s**pinosum) that are then taken through a series of further purification and milling steps to produce SRC. Some processors take ATC as a preferential feedstock for the production of GP carrageenan.

Carrageenan is produced by companies around the world, Table 13.1 shows the key players in the industry by region and also the technology employed. It clearly shows the regional split between SRC and GP production in Asia and AP and hybrid production in Europe and the Americas. Historically, Asia was the supplier of seaweedraw material which was exported to the west for processing. However, the situation today is quite different. There are currently 16 processors in Indonesia and 14 in the Philippines. Foreign operators, CP Kelco, FMC, Cargill, Kerry and CEAMSA have production plants in the Philippines but until recently there were no foreign operators in Indonesia. In 2015 however, the Chinese company Shanghai Brilliant announced that it would build a large ATC/SRC plant in Indonesia which (as of mid 2017) was due to start production "soon". Most of the seaweed grown in Indonesia is exported for processing (mostly to China). Only a third of Indonesia's *Kappaphycus* is processed domestically, mostly by small producers (<15,000 MT) and mostly industrial grades for pet food and ATC (Porse and Ladenburg 2015).

The Chinese companies, Shanghai Brilliant and Greenfresh are currently the number one and two carrageenan producers in the world respectively; they were reported to be taking <4,000 MT dwt mo^{-1} and <2,000 MT dwt mo^{-1} (respectively) of *Kappaphycus* from Indonesia for the production of GP and SRC (Neish 2015; CyberColloids own data). Neish (2015) reported that Chinese companies were producing carrageenan products that could be US$ 1–2 kg^{-1} cheaper than Indonesian and Philippines grades. Many Indonesian and Philippines companies were finding it hard to compete with China on a cost-basis. For Indonesian companies in particular, competition with China was also proving difficult in terms of end-product quality (Neish 2015). However, CyberColloids is aware that some smaller Chinese processors are now toll-manufacturing in Indonesia and the Philippines. Outside of Indonesia, the Philippines and China, carrageenan was also processed in Malaysia and Japan.

In Europe and the Americas, a small number of companies are perceived to be the key players with all predominantly focusing on the production of AP grades (Table 13.1). Albeit, most of these companies have production facilities in the Philippines which produced RC GP and/or SRC grades. In 2013, Neish and Msuya reported that most buyers were taking roughly equal splits of seaweed raw material from Indonesia, the Philippines and Zanzibar for their AP iota production. Certainly, in 2012, *Eucheuma* from Zanzibar was exported to key players in Europe, the Philippines, North America and Chile (Neish and Msuya 2013). Gelymar is an interesting exception to the western norm, with a wider range of production technologies (e.g. RC AP, RC GP and hybrid) all based in Chile.

Production in Europe and North America, in general, appeared to be steady with no closures or investment/new plants reported in recent years. With concerns over consumer attitudes, future investments may become difficult to justify. However, whilst production appears to remain steady, the market continues to restructure. DuPont recently announced (March 2017) that it would acquire FMC Health and Nutrition which included the carrageenan production facility in Rockland, Maine, USA.

In 2015/2016, the estimated production capacity for Europe and the Americas accounted for about 12% (10,500 MT dwt) and 17% (15,000 MT dwt) respectively of total global carrageenan production*c.f.* 45% (or just under 40,000 MT dwt) and 25% (about 22,000 MT dwt) for Asia-Pacific and China (estimated averages based on CyberColloids own data, Porse and Ladenburg 2015; Neish 2015 and summarized in Table 13.1 below).

CyberColloids currently estimates the global production capacity of carrageenan to be in the region of 86,000 MT dwt; Porse and Ladenburg's estimates (2015) are within range at 73,000 MT dwt whereas Neish (2015) reported much higher figures of over 110,000 MT dwt year^{-1} (Fig. 13.5 and Table 13.2 below). Neish (2015) does however state that the estimates given included data for operations that were not necessarily active at the time of writing. Porse and Ladenburg (2015) did not give estimates for the hybrid grades separately but those data were distributed across other categories.

When considering the breakdown of global production by carrageenan type, more SRC grades (kappa and iota) are produced than other type of carrageenan. In 2015/2016 SRC accounted for about 51% of the total global carrageenan production and most of this SRC (≈80%) came from *Kappaphycus*. In fact, kappa carrageenan in general, had a higher market demand and accounted for about 70% of all

Table 13.1 Key players by region showing types of carrageenan produced

		RC AP	RC GP	Hybrid	SRC
Europe	CPKelco (Denmark)	✓			
	Cargill (France)	✓			
	CEAMSA (Spain)	✓			
Americas	FMC (USA)	✓			
	Gelymar (Chile)	✓	✓	✓	✓
	Du Pont (Danisco)			✓	
Asia Pacific	CPKelco (Philippines)		✓		
	Cargill/Phil.Bioindustries		✓		
	Kerry (Philippines)				✓
	Shemberg (Philippines)	✓	✓		✓
	CEAMSA (Philippines)				✓
	Other Philippines		✓		✓
	Indonesia		✓		✓
China	Shanghai Brilliant (China)		✓		✓
	Greenfresh (China)	✓	✓		✓
	Other China		✓		✓

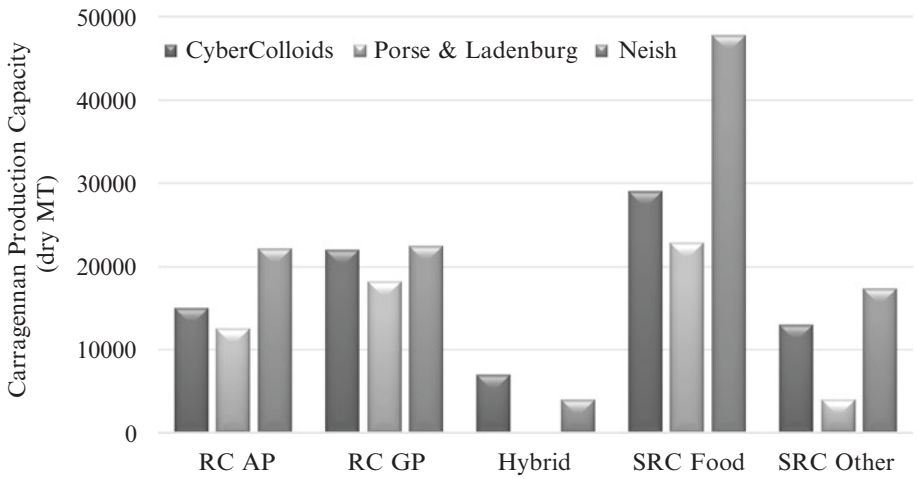


Fig. 13.5 Overview of global carrageenan production capacity in 2015/2016 (dry MT) by type. Based on recent industry estimates: CyberColloids own data for 2016; Porse and Ladenburg data for 2015 and Neish data for 2015. NB: RC = refined carrageenan; SRC = semi-refined carrageenan; AP = alcohol precipitated, GP = gel press; "Other" includes ATC/s, used in pet food, toothpaste and beer

Table 13.2 Estimated carrageenan production capacity (dry MT) by type and region

	RC AP	GP	Hybrid	SRC food	SRC other
Europe	7,000a	–	–	–	–
	6,900b	1,400b	–	–	–
	10,250c	–	–	1,000c	–
Americas	5,000a	1,000a	7,000a	2,000a	–
	5,000b	2,600b	–	1,500b	–
	7,000c	1,000c	4,000c	2,250c	–
Asia Pacific	3,000a	10,000a	–	22,000a	12,000a
	1,900b	6,200b	–	20,000b	7,000b
	3,950c	8,000c	–	30,700c	9,950c
China	–	11,000a	–	5,000a	1,000a
	–	15,000b	–	6,000b	–
	1,000c	11,500c	–	11,000c	1,000c
Total	12,500–22,500	18,200–22,520	4,000–7,000	22,885–47,830	4,000–17,400

2015/2016 data based on (a) CyberColloids own data (2016); (b) Porse and Ladenburg (2015); (c) Neish (2015)

carrageenan produced globally *c.f.* 20% iota (CyberColloids own data, Porse and Ladenburg 2015). SRC production capacity in 2006 was estimated to be in the order of 16,000 MT dwt (CyberColloids 2012) and thus, on average, doubled in the last 10 years. Current estimates were quite wide-ranging, viz. 23,000–48,000 MT dwt and reflected differences in industry intelligence.

SRC is by nature slightly cloudy (due to the cellulose content) but for many applications high clarity and gel strength are not as important as other functional properties. For this reason SRC is used as a cheaper alternative to RC. Market prices for SRC (as of March 2017) were in the range: US$ 6–8 kg^{-1} (CyberColloids own data). Semi-refined kappa carrageenan in particular, is used in processed meat products, to extend the meat and other sources of protein and thus add value. In some cases, SRC also gives some additional technical functionality, e.g. reduces "tiger striping" or visual defects in processed meat products. Current growth in the carrageenan market, as a whole, is being driven, to a large extent, by increased demand for cheaper and better value meat and meat-based products. SR iota carrageenan is also used in meat-based products (to a much lesser extent than kappa), in various carrageenan blends in order to add specific functionality and also has applications for beer refining.

A key, non-food application for SRC (both kappa and iota) is in pet food. SRC appeared to be finding renewed uses in pet food (from discussions with pet food industry contacts). When dry food formulations became popular, the demand for pet food-grade carrageenan fell but a new trend for high diversification in new, wet/moist food formulations is driving the re-use of carrageenan.

The global production capacity for refined carrageenans in 2015/2016 was in the range of 18,000–22,500 MT dwt of GP and 12,500–22,500 MT dwt of AP. Note that estimates for AP were not exclusively for iota carrageenan but also included other AP grades. Refined GP carrageenan has high gel strength and high clarity. It typically has a slightly higher cellulose component than AP carrageenan (≈0.5%) and also contains residual levels (1–2%) of potassium chloride from the extraction process. The residual potassium chloride means that GP carrageenan always gels on the addition of water and without the addition of ions, unlike AP carrageenan grades. These properties render refined GP carrageenan ideal for use in jellies and confectionery, particularly in Asia. In fact, most GP carrageenan is used in the Asian market for jellies and confectionery and this particular application is one of the key drivers in the global market at present.

Refined AP iota carrageenan from *Eucheuma* has particularly high purity and high clarity. Consequently it has a higher market value than refined GP and the market price is higher than that of refined kappa. Consequently, its main application is in high value products such as toothpaste. Current market prices for AP and GP (as of March 2017) were US$ 12–14 kg^{-1} and US$ 9–11 kg^{-1}, respectively (CyberColloids own data). Iota carrageenan is also used in dairy desserts as it forms soft gels and has good freeze/thaw stability. In 2016, CyberColloids reported that the production of AP carrageenan had fallen during the 1990–2000s, we attributed this decline to a rise in SRC and GP technology and the increased demand for SRC and GP kappa grades.

Since 2006, production of hybrid grades of carrageenans from South American red seaweeds has grown. Recent estimates (2015/2016) for production capacity ranged from: 4,000–7,000 MT dwt (Fig. 13.5 and Table 13.2). The hybrid carrageenans have particular applications in dairy products as they provide unique mouth-feel attributes which are highly desirable to food formulators. As such, these carrageenans command a higher market price, about US$ 14–17 kg^{-1} (as of March, 2017; CyberColloids own data). There has been strong growth in the Asian dairy market where these grades are being utilised. The sustainability of

the South American hybrid production is a long running debate within the carrageenan industry but, as of 2017, a crisis in raw material supply had not happened. However, Chilean producers, like Indonesian, appear to be shifting towards the export of locally produced carrageenan, whilst exports of seaweedraw material dropped. There were no apparent restrictions in the availability of raw materials as of early 2017 (CyberColloids own data).

CyberColloids' current (March 2017) estimate for global carrageenan usage, as based on end-sales data, was for 68,000 MT dwt which equated to approx. 80% utilization of the estimated global production capacity. Percentage utilization across different technology categories varied from 60–90% (CyberColloids own data). Table 13.2 above provides a regional breakdown of carrageenan production capacity by type, based on our 2016 estimates and those given in the most recent industry reports (Neish 2015; Porse and Ladenburg 2015). To the best of our knowledge, and based on discussions with industry contacts, it appeared that production capacity and demand for the refined AP were tightly matched, whereas there was an over-capacity for the SRC grades and a possible over-capacity for GP. The magnitude of this over-capacity is debatable as it is difficult to confirm production figures for Indonesia, in particular. As of March 2017, we believed the utilization of current processing capacity in Indonesia to be in the range of 50–70%, although some industry contacts reported this to be even lower. The demand for hybrid grades remained strong, whilst production was rising.

13.5 End-Use Markets

Carrageenan is used in an extremely diverse range of food products but most typically those that are based on, or contain, ice cream, meat and poultry, dairy products (including cheese and cream, dairy drinks), non-dairy (e.g. nuts and seeds) drinks and water-based jellies (see Hotchkiss et al. 2016a for more detail). Currently, over 80% of the global carrageenan production is utilised by only three major application sectors: (i) processed meats; (ii) dairy and (iii) desserts and jellies (Fig. 13.6). Growth in demand for these three, end-use markets was steady over the past 10 years (i.e, from 2006–2015, with an estimated growth of 1.5–3%, per year, in each sector (CyberColloids own data). This growth reflected the global trend for increased demand for processed/convenience foods and was in response to both population growth and changes in regional economies. Convenience foods are a target for consumers either forced to seek value for money during recession, or those that are experiencing improved living standards and are able to buy more diverse food offerings.

The demand for processed meat products that offer value to consumers, i.e. those made from comminuted meat (burgers, nuggets), injected and reformed meats (hams, chicken rolls) and emulsions (frankfurters and sausages) had risen substantially and remains a key driver for the global production of SRC (kappa in particular and iota to a much lesser extent). In terms of the number of new products appearing in the market place, it appeared that little changed between 2007–2016, with the level of innovation remaining static at 10–11% of new products launched globally (Fig. 13.7).

The dairy sector was still dominated by the use of RC AP grades and SRC grades did not appear to have made any significant inroads, except in chocolate milk and ice cream. However, despite significant growth in the Asian dairy market and high global innovation in terms of new products in the market, the production of RC AP fell from >20,000 MT dwt in 2006 to about 12,500 MT dwt in 2015. The question as to how long the RC AP grades could defend themselves against 'cleaned up' SRC grades and more cost-effective hybrid grades still stands.

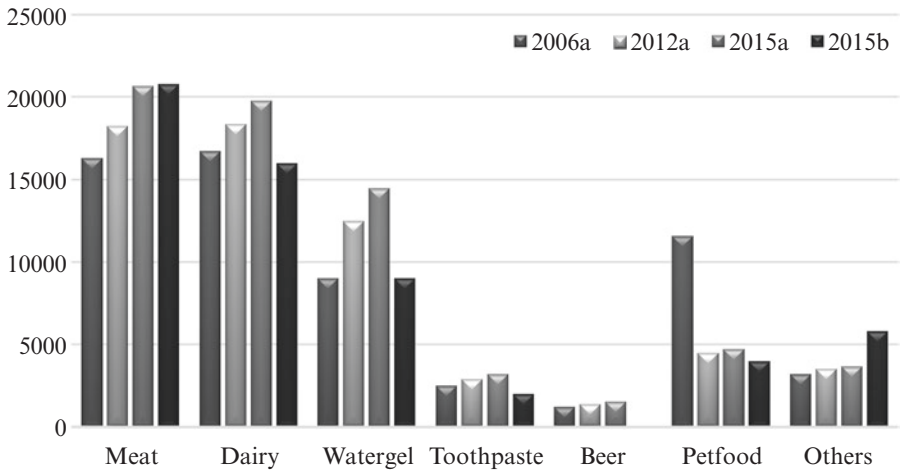


Fig. 13.6 Carrageenan sales by end-use showing major categories; estimated volumes (dry MT) for 2006, 2012 and 2015. NB: Dairy also included ice cream and milk based drinks, water gels included jellies, confectionery and shelf stable desserts (a = CyberColloids own data, b = Porse and Ladenburg 2015)

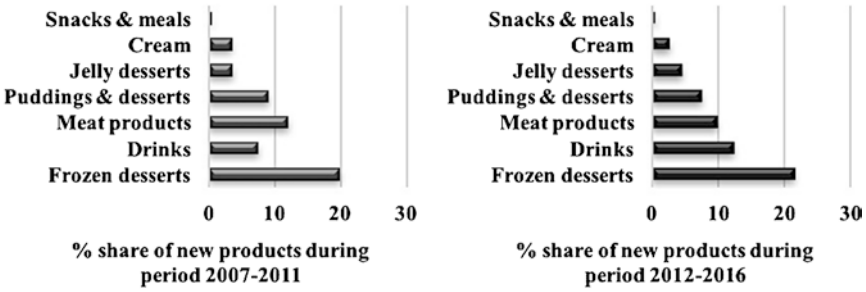


Fig. 13.7 New food products appearing in the global market containing carrageenan (refined and semi-refined grades) for the periods 2007–2011 and 2012–2016. The diagram shows the percentage share in key application sectors. NB: Frozen desserts included ice creams and frozen yogurts (CyberColloids 2017)

SR kappa is used as a thickening and suspension agent in flavoured milk drinks, e.g. chocolate milk and iced coffee. From 2007–2016, there appeared to be some growth in the use of carrageenan in new, milk-based drinks but note that the data presented here also includes use in non-dairy milks (e.g. nut and seed-based) and meal replacement drinks which were a globally growing sector.

The rise in demand for RC GP for water jellies and confectionery was seen to be very much an Asian market phenomenon, being linked to population growth and rising standards of living. Jelly-based convenience foods like snacks and shelf-stable desserts (as opposed to chilled/frozen dairy based desserts) are extremely popular. As the RC GP technology was very reliant on seaweeds which were cultivated in south-east Asia, any future demand would likely be satisfied by regional suppliers.

Significant smaller market sectors for carrageenan included: toothpaste, pet food and beer. Refined AP iota carrageenan has a niche application in toothpaste. It is used as a thickener, but has other key attributes, most importantly, stability against enzymatic degradation, good flavour release and rinse-ability making it ideal for use in toothpaste. The use of SR grades (mostly kappa with some iota blends) in beer had generally been steady to the time of writing however, there was also a noted move towards using less processing aids in beer, the outcome of which could mean a decline in the use of carrageenan. This awaits to be seen.

As previously mentioned, a revival in the use of carrageenan in pet food has been reported. Traditionally, this was one of the significant, non-food sectors which utilised SRC. Carrageenan is used as a retort-stable, gelling agent and stabiliser in jelly and gravy-based, canned and pouched products and more recently in chewable snacks as a binder and texturant. It is difficult to judge growth in this sector in terms of new products in the market, as in many regions, carrageenan is not declared on the ingredients list. However, in recognising this renewed global growth, changes in consumer attitudes in North America appeared to be having an impact. As of 2016/2017, North American pet food manufacturers were seeking replacements for carrageenan, however, since cost-effective alternatives were not readily available, sales of carrageenan appeared to be unaffected.

13.6 Regional End-Use

In 2016, the global carrageenan market was reported by Markets and Markets (2016) to be worth an estimated US$ 758 Million, based on a global market size of approximately 57,000 MT dwt (Fig. 13.8). This is in line with hydrocolloid industry estimates which put a value of US$ 600–700 Million on the market for which the demand was in the order of 60,000 MT dwt year^{-1} (Hotchkiss et al. 2016b; Seisun 2016; Porse and Ladenburg 2015). Markets and Markets (2016) predicted that the market volume would reach 70,723 MT dwt with a value of US$ 1047 Million by 2020 (CAGR of 4.41% and 6.66%, respectively).

Markets and Markets (2016) reported Europe and North America to be the major markets for carrageenan. The only regional data that CyberColloids has been able to verify is that for the North American markets (including USA, Canada and Mexico). CyberColloids estimated this to be around 20,000 MT dwt year^{-1} for 2016, as based on import data. It seems reasonable therefore that the Markets and Markets estimates of end-use in other regions were credible (CyberColloids own data).

In terms of the number of new products appearing in the market which contained carrageenan (refined and semi-refined), there was a substantial increase 2007–2016, which indicated that there was probably growth in the use of carrageenan in all global regions (Fig. 13.9). Europe remained the region with the highest level of innovation with >40% of the global share. There appeared to have been a shift in relative positions of the North American and Asia Pacific markets with the most products launched in Asia Pacific during the 2012–2016 period (Fig. 13.9). These observations could be illustrative of changed consumer attitudes towards carrageenan in North America, or simply the rise in carrageenan usage in Asia.

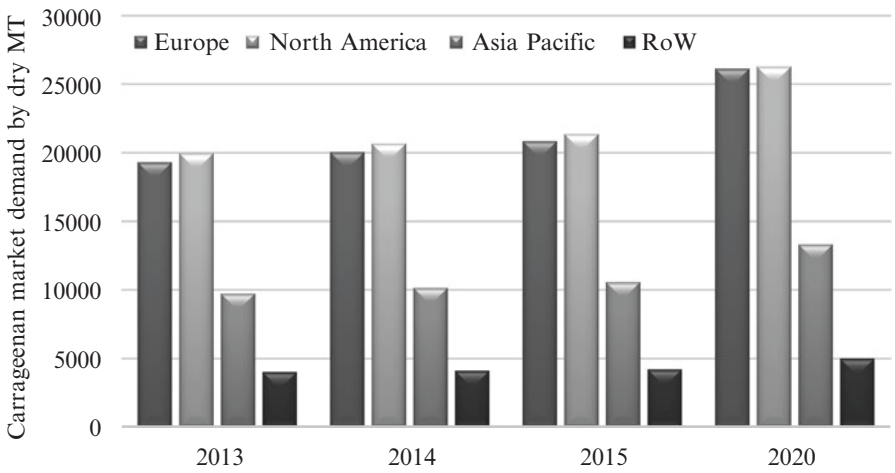


Fig. 13.8 Global carrageenan market by region from 2013–215 with projected demand for 2020. NB: RoW = Rest of World (Data by permission Markets and Markets 2016)

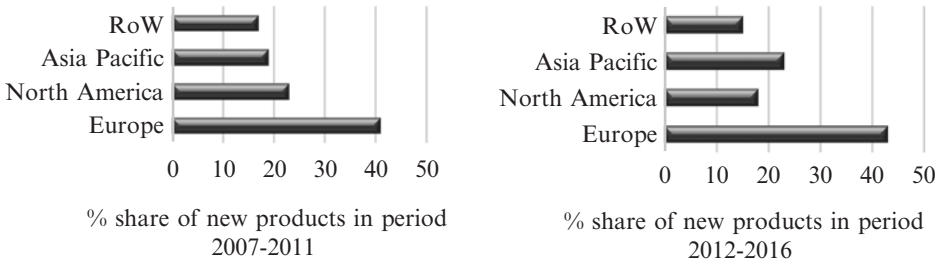


Fig. 13.9 New food products appearing in the global market place that contained carrageenan (refined and semi-refined grades) by region. For the periods 2007–2011 and 2012–2016. Showing % share by region. NB: Row = Rest of World (CyberColloids 2017)

13.7 Looking Forward – An Industry Perspective

In very broad terms, today's carrageenan industry could be seen as being divided into three major sectors based on production technology. Each satisfying its own end-markets and each being subject to particular fluctuations in supply and demand. These sectors are, the AP and hybrid sector, the GP sector and the SRC and ATC/S sector (Fig. 13.10). However, as already highlighted, there was also a clear geographical split between the production of AP and hybrid grades in the west and that of SRC and GP grades in Asia which was essentially linked to raw material supply.

Today (2017), the AP and hybrid sectors are characterized by a relatively small number of players that service high value, niche markets, including toothpaste and pharmaceutical, but this sector was clearly dominated by the dairy market. The AP iota market was generally considered to be mature and production of RC AP had fallen over the last decade. There appeared to have been little investment in the west, despite growth and high innovation in the dairy market (particularly in Asia). Demographic growth in middle-class consumers in Asia (in particular) was one of the key drivers for the dairy sector which was expected to continue growing. The use of Chilean seaweeds to produce carrageenan for the dairy sector had grown over the past 5 years (CyberColloids own data) and given this, concern remained within the industry for the future, sustainable supply of these Chilean seaweeds.

Key players in the AP and hybrid space appeared to be adopting different strategies in order to deal with any potential threat to raw material supply from Chile. Since 2013, Cargill openly announced their strategy to diversify their product offering and to utilize more "sustainable" seaweeds that are farmed in Asia. Chilean-based Gelymar however, were proactive in gaining a better understanding of the naturally available resource and invested in the development of resource management strategies and cultivation programmes for some of the key species (from discussion with Gelymar).

Thirty years ago, there was virtually no left hand side (GP and SRC) to the schematic illustrated in Fig. 13.10. There has been a relative explosion in seaweed cultivation and in carrageenan production capacity in South-east Asia. Despite growing markets and demographic changes, there was undoubtedly a significant over-capacity for SRC and probably GP. We have to ask what is going to happen with all of this over capacity and whether it will force the cut back or closure of some facilities?

The government roadmap for the Indonesian seaweed industry was reported to be driving the construction of several new carrageenan processing facilities, with the aim for Indonesia to become the largest seaweed processor in the world. We have been informed that 20 new plants were planned, eight of which had been built so far (as of March

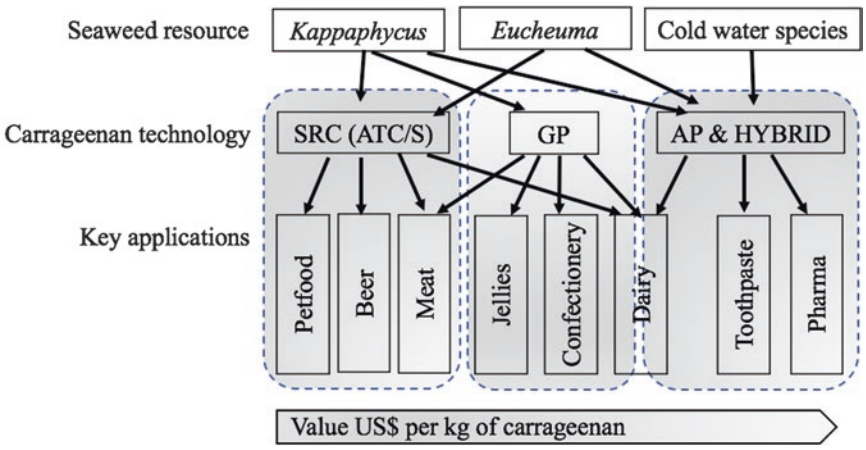


Fig. 13.10 Schematic of the carrageenan industry at present, showing major segmentation by seaweed resource, production technology and key applications

2017). With usage currently reportedly at 50–70% (or lower), this investment appeared to be somewhat unnecessary. However, the roadmap was also driving a restructuring of the industry, with the intent to shift away from export of high volume, cheaper grades, towards the development of higher value products and blends for domestic markets (from discussions with Indonesian processors).

Changes to the Indonesian situation will likely have most impact on China as the primary importer of their seaweed. However, the number one Chinese company: Shanghai Brilliant has located a facility to produce 10,000 MT year^{-1} of ATC/SRC in Indonesia, could this be indicative of future changes? With the Chinese industry being dominated by only a few large players, such a change could result in smaller companies being squeezed out. We have already heard reports that smaller, Chinese producers were toll-manufacturing in Indonesia and the Philippines.

Given the above however, over-capacity still seems likely, as does the reality that processors will have to diversify and add value if they are to remain competitive and prevent closures. If this is the case, then it is possible that it will be in the SRC and GP sectors of the industry that we will see the most innovation going forward. Multi-stream processing or biorefinery approaches are not new phenomena for the seaweed industry and are indeed discussed in detail elsewhere in this book. The MUZE (**m**ulti-stream **z**ero **e**ffluent) concept was proposed several years ago as a straightforward means to cost effectively and sustainably produce SRC/ATC grades, in addition to recovering other value-added products, such as extracts for the agri-horticulture sector (Neish 2012). Since then, it has been evaluated as a means to produce carrageenan and biostimulant extracts from *Kappaphycus* in India (Neish 2013) and to add value to the carrageenan/seaweed value-chain in Zanzibar (Neish and Msuya 2013). From discussions with processors, we are aware that there does appear to be a general interest to add value through diversification and multi-stream processing, particularly in Indonesia. According to an analysis of the commercial seaweed market (Grandview Research 2016), the category of liquid seaweed extracts is one of the predicted growth areas going forward, in particular to service the food, cosmetics and agri-horticulture sectors.

On a more sophisticated level, the seaweedbiorefinery concept has become a key focus for "Blue Economy" research strategies. Various models are proposed that deliver a diverse range of product streams and generally end up with a hydrocolloid (fiber) stream once all other high value components have been removed (Note: unless intended for generation of biofuels). Seaweed in general, has become a hot topic for research with national and regional marine strategies being implemented to promote sustainable exploitation of marine resources and to re-build and re-vitalise coastal, marine economies. As such, funding and opportunities for new cross-disciplinary research have probably never been better. Research into fields that have not traditionally been associated with the traditional seaweed industry, such as biotechnology and bio-pharma, are now well and truly on the radar and some products which exploit the bioactive properties of carrageenan (e.g. anti-microbial and anti-viral activity) are already commercially available.

The hydrocolloids industry, being based on the extraction of target polymers, is inherently wasteful and generates effluent streams through processing. In a world where there is a global push towards achieving greater resource efficiency, minimization of waste and food security, there is certainly ample room for the industry to look for more innovative and smarter 100% usage of its raw materials.

Seaweed in general is also enjoying renewed interest from the food industry. Consumer and industry media has been reporting a "surge" in the use of seaweed and microalgal ingredients and has gone as far as to say that seaweed and microalgae are driving NPD in many sectors (Food Ingredients First 2017). In 2016, seaweed was considered to be a top food industry trend with 30% growth in the US snack market alone (worth of $500 million) being reported (FoodBevMedia 2015; NNB 2016). However, the situation

with regard to carrageenan was fundamentally different and the "Carrageenan Controversy" (Bixler 2017) as it is increasingly referred to, was undoubtedly having an impact on consumer attitudes in some markets. The media-hype surrounding the misguided portrayal of carrageenan as being unsafe for human consumption has been around for a number of years, but was more recently ramped up. There is now widespread misinformation and confusion being circulated in the social media and consumer news.

Changes in consumer attitudes towards the use of carrageenan in food and pet food markets in North America, in particular, were very apparent, as of early 2017. The decision by the NOSB (**N**ational **O**rganic **S**tandards **B**oard) which advises the US Department of Agriculture, to ban carrageenan from organically registered products would undoubtedly have further negative impacts in the North American markets in particular. Indeed carrageenan was being replaced by some companies, particularly in premium brands such as ice cream. In 2016, Nestlé publically rolled out a range of new, "simpler" ice cream formulations, in which carrageenan and xanthan gum were replaced with other hydrocolloids, with a more "natural" image, i.e. pectin. We have received word of an estimated 30–40% reduction (globally) in carrageenan intelligence usage in 2016, however, these figures were not supported by the data which suggested that imports of carrageenan to the US were down by only 4–5% (CyberColloids own data).

The US pet food industry was also reporting similar consumer driven changes. In the US, carrageenan is declared on pet food labels, unlike in Europe, where it falls under a natural ingredient classification. Manufacturers are seeking "clean label" ingredients and some premium brands (especially cat food) started to replace carrageenan with agar (also a red seaweed extract; from discussions with industry contacts). The decision to replace carrageenan very much depended on the cost differential. The pet food industry is typically cost-driven and is based on smaller margins for large volume production. This market segment would therefore be particularly sensitive to increased ingredient costs. There did not appear to be a significant push, as yet, for carrageenan to be replaced by non-US pet food manufacturers (from discussions with industry contacts).

As with pet food, the decision to replace carrageenan in food also depends on the cost differential and at present, replacement is mostly being seen as a brand protection strategy for premium products only. Carrageenan is a relatively cheap, reliable ingredient and is typically only used at quite low dose rates. Even so, to replace carrageenan with agar or pectin could cost around three times more and to be replaced with gellan could cost up to ten times more. However, cost is not the only barrier, as some functionality and organoleptic issues may also arise from the replacement of carrageenans with other texturizers. It remains to be seen whether, and how far, this trend would spill-over into non-premium brands and applications, or even into products where higher dose rates were required to achieve rheological functionality.

It will indeed be interesting to see how the North American situation plays out if such trends continue. Will the corporate, western companies invest, or take a stand against the media buzz in order to chase the North American market or is it too risky? Or, will they look to the rapidly growing Chinese and other Asian markets where consumer attitudes and market demands are different? Outside of North America, we are seeing a response to the wider global trends for "label friendly" ingredients and healthier foods and of course, carrageenans (like all other hydrocolloid additives) have been targeted in this respect, particularly in Europe where carrageenan carries an E number (i.e. E407 or E407a). We are aware that manufacturers in some sectors are addressing the issue of carrageenan replacement and undoubtedly would consider a cost-effective alternative if presented with one.

Replacement of hydrocolloids with label friendly alternatives is not a new theme, hydrocolloids are being substituted with ingredients that have a more natural perception. One exciting and growing area, is the use of functional food fibres. Functional food fibres are typically holistically processed vegetable, fruit and cereal materials which contain both soluble and insoluble fibre fractions, with different textural and often physiological functionalities. These fibres differ in functionality from standard fibre equivalents in that processing has been applied in order to activate, or modify, certain characteristics which provide improved water-binding, viscosity, gelling behaviour and mouth-feel properties. Some fibres even have fat mimetic properties on account of their superior water-binding capacity (Hotchkiss and Trius 2016a, b). Products made from oat, citrus, vegetable and cellulose-rich sources are currently in the market and are finding increased applications in healthy formulations. One seaweed fibre derived from *Gracilaria verrucosa* was launched into the market relatively recently (Phytafiber ® from Java Biocolloid). It is marketed on the basis of its natural image, water-binding and gelling functionality and as a source of dietary fibre. The soluble fibre component here is agar. The question arises as to why similar products are not available from the carrageenan-bearing, red seaweeds or indeed, for that matter, from alginate-bearing, brown seaweeds. There seem to be many opportunities to be realised in this regard.

Given our recent observations and returning to the general overview of the industry as depicted in Fig. 13.10 above, it was clearly evident to us that a further polarization of the industry between Asia and the west was beginning to occur. Both in terms of supply and markets. The carrageenan controversy was undoubtedly having an effect in the west (as of March 2017) but it was not a global issue and was unlikely to impact Asian markets, or suppliers in the near future. There

had been no reported investment in the industry, by key players, in the Americas and Europe in recent years and some appeared to be simply boosting their efforts elsewhere in the hydrocolloids space, e.g. CP Kelco making further significant financial commitments to pectin in 2013. Is this indicative of further stagnation and possibly the start of the decline of the carrageenan industry in the west? This remains to be seen and will no doubt be followed by key commentators. With production and markets growing rapidly in Asia, we predict that this is the area where there will be the most innovation going forward.

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